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INSECTS ASSOCIATED WITH MIDWESTERN OXIDATION LAGOONS

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TERMINAL PROGRESS REPORT

Grant No. WP-00718

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Institution: University of Missouri, Columbia, Missouri

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Summary of Progress

The specifically stated aims of this project were:

"1. To study intensively the entomological fauna of sewage lagoons including insects, crustacea, mites, spiders, and sowbugs in all sorts of lagoons from the newest, rawest ones to old ones, including primary and secondary lagoons. This must be done on a year-around basis, and for several consecutive years, with particular attention to seasonal fluctuations of aquatic populations.

2. To investigate the relationships between predator and prey species in lagoons and determine which predators are most effective in suppressing midges and mosquitoes.

3. To determine whether insect pathogens are present, what their possible role might be, and whether they can be manipulated artificially.

4. To investigate the possibility of manipulating insect populations in ways which maintain a lagoon in good balance. As a corollary of this, to study means of lagoon management which will have the same result.

Our long-term goal is to acquire basic biological data on midwestern sewage lagoons so that these will be available to those who need them, and possibly to forestall some of the potentially serious consequences which could develop with improper management of such lagoons."

Progress toward achievement of the aims listed above is summarized as follows (numbered to correspond to the aims cited):

1. The original problem which demanded answers was an intolerable mass emergence of midges (Diptera: Chironomidae) from municipal lagoons in a small town in northeastern Missouri. The recurring appearance of vast swarms of these insects, it was feared, would have a ruinous effect on real estate values and civil suits were threatened. Additionally, from time to time

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reports of problems with mosquitoes breeding in lagoons and infesting nearby habitations were received. However, the need for information concerning midges seemed to be the more urgent and this investigation concentrated first on a study of these insects. Concurrently, data were gathered on other insects associated with lagoons.

INSECTS OTHER THAN MOSQUITOES

Qualitative investigations revealed 63 species of aquatic insects occurring in the 18 central Missouri lagoons which were sampled. Midges (Chironomidae) occurred in all lagoons but three species predominated, viz., Glyptotendipes (Phytotendipes) barbipes (Staeger), Chironomus (Chironomus) plumosus (Linnaeus), and Tanypus punctipennis Meigen.

Quantitative data showed the association of species to be divisible into three distinct types based on one or more of the three dominant primary species of midges. It was also possible to categorize lagoons into three types using age, sewage load, and relative abundance of midge larvae as parameters (Tables I, II, and Fig. 1).

Species of aquatic insects other than midges made up only a small percentage of the total number collected (Table III). Those species of Diptera which are usually associated with water of high organic matter content showed a progressive increase in density from the more lightly loaded, newer lagoons to those which were heavily loaded and older. Beetles also were progressively more diverse but at least some species were found in all lagoons. One benthic dragonfly naiad, Plathemis lydia Drury, was common in all lagoons.

Not listed on Table III were some aquatic mites (Hydracarina) which were taken from a lagoon but which was not one of those included in the study series. No crustaceans or spiders were taken in any of the samples.

The results of this part of the investigation are being published by Kimerle and Enns (1968). However, only nine species of midges are reported in that paper whereas continued collecting has revealed three more bringing the total to twelve (cf. Fagan & Enns, 1966).

Of the twelve species of midges found breeding in oxidation lagoons in central Missouri, one species only (Glyptotendipes barbipes Staeger) was positively associated with mass emergence and this is probably the species responsible whenever a nuisance problem is created by excessively abundant midges in this area. An intensive study of its biology in lagoons, therefore, was undertaken. The results of this study have been published by Fagan and Enns (1966).

MOSQUITOES

From the outset of building the earliest oxidation lagoons it was feared, and later proven, that mosquitoes would and did breed in them. The Culex pipiens complex was known to breed in lagoons and Culex tarsalis also was reported to breed there. Since these two species are known vectors of encephalitides, it becomes imperative to know their breeding and population potential in lagoons. Considerable efforts were made in the study reported here to determine species composition and to acquire biological data in various types of oxidation lagoons in central Missouri. Data summarizing the characteristics of the eight lagoons which were studied are given in Table IV and the productivity of each lagoon based on numbers of egg rafts and larvae is given in Table V. Results of this part of the investigation are being published by Smith and Enns (1968).

The characteristic mosquito population associated with the lagoons consisted of twelve species, of which only five were found breeding within the lagoons proper (Table VI). Data on adult mosquitoes were obtained by both light trap and human-bait biting collections. Larvae were also reared to verify identifications and to make sure adults of all species would be represented.

The most annoying and abundant adult mosquitoes in the lagoon environs were the Culex pipiens complex, Anopheles punctipennis, Culex erraticus, and Aedes trivittatus. Adults of the C. pipiens complex, A. punctipennis, and Culex salinarius were omnipresent in all lagoon environs, but C. salinarius adults were never abundant. C. erraticus and C. tarsalis adults were observed in the environs of every lagoon also except for one trailer court. C. erraticus adults were present from June through October (peak abundance during August) and readily attacked human bait while C. tarsalis adults were observed infrequently from August through November and were never taken in human biting collections.

Culiseta inornata adults occurred in all lagoon environs except certain municipal and trailer court lagoons. The seasonal distribution and biting behaviour of this mosquito was unique in comparison to the other mosquitoes associated with the lagoons. C. inornata was the first species to appear in the lagoons and was the last to be collected in late fall. Adults were present from May through June, virtually absent during July and August, and reappeared again in September and October. Adults were frequently identified from biting collections during the spring and early summer, but not during the terminal portion of their cycles, i.e., September through October.

Mosquitoes recorded less frequently included Aedes canadensis, Aedes triseriatus, and Aedes vexans. A. canadensis was present during early spring and summer while other Aedes species were recorded from June through November. A. trivittatus was the most abundant flood-water mosquito in the lagoon environs, and was recovered only from diurnal biting collections. Anopheles quadrimaculatus and Psorophora ferox adults were occasionally taken.

As a corollary of the studies on mosquitoes associated with oxidation lagoons, a review of the entire mosquito fauna in Missouri was undertaken. Nine genera including 53 species were recorded for the state. Aedes hendersoni Ckll. and Aedes riparius D. & K. were taken for the first time in the state. In summary, 21 species of Aedes, 6 of Anopheles, 8 of Culex, 3 of Culiseta, 1 of Mansonia, 2 of Orthopodomyia, 10 of Psorophora, 1 of Toxorhynchites, and 1 of Uranotaenia are now known to occur in Missouri. These include collections made or examined from 74 of the 114 counties in the state. The greatest concentration of mosquito species is in the southeastern lowland counties as would be expected. Keys for the identification of adult females, adult males (by terminalia), and fourth instar larvae of the mosquitoes in Missouri have been constructed together with synopses of general and specific characteristics of each genus and species. County maps have been prepared showing the distribution of each species in the state and illustrations have been made of the larval characteristics and of the male terminalia. The bionomics and medical importance of each species is discussed also with particular reference to those associated with oxidation lagoons. The results of this aspect of the investigation have not been published and at present no suitable outlet for publication seems in prospect. Efforts to get this information published will be continued. A simple preliminary checklist of mosquito species in the state was published by Smith and Enns (1965). Subsequent study showed that list to be inaccurate, in part, since it listed 57 species, the errors being due to overconfidence in literature records. Table VII presents a list of the genera and species of mosquitoes now known to occur in the state. The infrequent occurrence of Anopheles punctipennis in certain lagoons suggests the possibility of future adaptation to these man-made environments by this species. There is a suspected relationship between certain anophelines and California encephalitis. Nothing is known of this arbovirus in Missouri.

3. Numerous arthropod predators belonging to the families Belostomatidae, Nepidae, Notonectidae, Dytiscidae, Gyrinidae, Hydrophilidae, and Chaoboridae were observed in the study lagoons. Among those most frequently encountered were two dytiscid beetles, Laccophilus fasciatus Aube and L. maculosus Say. These two species occurred in most of the lagoons, with the former the more abundant.

A laboratory study was conducted to ascertain the predation potential and predatory behavior of the two Laccophilus species. Specific objectives were to: (1) determine the predation potential on various instars of mosquito and midge larvae, (2) compare the predation potential for each sex of the dytiscids, (3) discover the effects of substrate on predation of midges, and (4) ascertain the effect of reduced visible light in the predatory activities of these two species of Laccophilus. The results of this study have been published by Roberts, et al. (1967).

In general, the predation potential for the two species of beetles was basically the same for third and fourth instar mosquito larvae (C. pipiens). Predation on mosquito pupae was less than half that for larvae.

L. maculosus appeared to be considerably more effective on midge (G. barbipes) larvae than was L. fasciatus.

Data obtained on differences in predation values between sexes were erratic and inconclusive but there appeared to be no significant differences in either species or on any prey.

The substrate had a rather pronounced effect on predation of midge larvae. Predation dropped sharply within the first three hours after midge larvae hatched from the eggs. This was due to their ability to build silken tubes in the sand substrate which afforded them protection for the remainder of their larval lives. Predation on midge pupae was practically nil.

Contrary to some reports in the literature that dytiscids are strictly diurnal, our studies showed that predation also occurs when visible light is greatly reduced or absent. However, the erratic results indicate that predation is probably due to chance meetings of predator and prey as opposed to prey-seeking in at least some visible light.

Consideration was given to the possibility of introducing predaceous beetles into lagoons where their populations were low. In the few instances where this was tried, no further trace of the beetles was found after release. The factors present in some lagoons that are conducive to dense dytiscid populations have not been determined. Further studies of these environmental requirements are needed.

The use of small fishes such as the mosquito-fish, Gambusia affinis, has long been advocated as a means of controlling midges and mosquitoes in various impounded waters including oxidation lagoons. Municipal lagoons around Columbia, Mo. are routinely stocked with these fish. In most years, the fish population perishes in the winter but is artificially replaced in the spring. These fish breed prolifically in the lagoons and very large populations are built up.

In the present study, in addition to observing the Gambusia released by city sanitarians, several species of small fishes were obtained from the Missouri Conservation Commission for trial releases in lagoons. Gambusia and bantam sunfish (Lepomis symmetricus) were released in one lagoon in May, 1965. They thrived until a sanitation crew mistakenly treated this lagoon with an oil plus insecticide spray in June. This eliminated all the fish.

Goldfish (Carassius auratus) had been introduced by the Conservation Commission into a small lagoon on a wildlife area. This lagoon had such a light load of sewage as to produce very few midges and no mosquitoes. The fish, however, were thriving and had not only survived but reproduced here for two years. Their efficiency in controlling insects is open to question.

Other fishes experimentally introduced into lagoons included golden shiners (Notemigonus chrysoleucus), green sunfish (Lepomis cyanellus), red-ear sunfish (Lepomis microlophus), bluegill (Lepomis macrochirus), black bullhead (Ictalurus melas), and a species of Tilapia. As far as determinable, all fared well through the summer but were eliminated in the following winter. No data were obtained on their efficiency in insect control.

As often happens in new impoundments in this area, green sunfish occasionally were found in lagoons where no deliberate artificial stocking was known to have occurred. The origin of these fish remains unexplained.

A single instance occurred in 1963 when a pathogen appeared to decimate a population of midges in a lagoon. It proved to be impossible to propagate or even maintain the disease in the laboratory and pathologists were unable to determine the causative organism. Symptomatically, however, it caused the chironomid larvae to turn from their usual red color to a sickly grey, followed quickly by death of the larvae. No further diseased specimens were found in succeeding years but it was obviously a very deadly pathogen. It might have been a virus but more probably was a microsporidian. There are reports in the literature of microsporidians exterminating large populations of midge larvae.

WATER QUALITY

From May, 1965 to August, 1966, water in the various lagoons under study was analysed in accord with standard procedures for such examinations. Routinely, readings were made for air and water temperature, turbidity (Secchi disc), pH, dissolved oxygen, carbon dioxide, hardness, and alkalinity (both phenolphthalein and total). We were unable to get ammonia nitrogen, nitrite nitrogen, and phosphates. These data differed in no significant way from those reported in the literature for similar lagoons.

The greatest benefit derived from the water quality readings was the information gained on daily fluctuations of dissolved oxygen. Perhaps the most important and least understood aspects of lagoon management is the maintenance of aerobicity at all times, the year around. About an equal amount of adverse public relations results from allowing a lagoon to become anaerobic as from allowing it to produce mosquitoes.

In the lagoons under study, a complete range from chronically anaerobic to almost permanently aerobic conditions prevailed. A lagoon was classified as anaerobic when the dissolved oxygen reading was less than 2 ppm.

Two of the study lagoons were usually anaerobic, both being animal waste lagoons, one at a swine farm and the other at a Humane Society installation. Even during daytime sampling the latter was anaerobic in four of five daytime sampling periods and invariably anaerobic during

the hours of darkness. This lagoon was almost a classical instance of mismanagement. It was greatly overloaded (usually), primarily with dog kennel wastes, the surface of the water covered with hair and grease, and vegetation growing luxuriantly in and around it. Concurrent with the anaerobic condition was the odor of hydrogen sulfide. No midges bred in this lagoon but literally thousands of rat-tailed maggots (Eristalis tenax) and mosquitoes (Culex pipiens complex) were present. When the grass was eliminated and the grease removed from the surface, the lagoon became aerobic but then it was sprayed with oil to kill the mosquitoes and it reverted to anaerobic conditions.

The troublesome swine farm lagoon was a primary cell which drained into a secondary cell. The primary cell was greatly overloaded and there was very scanty flow of water between the two cells. The primary cell was anaerobic on an average of two out of six daytime sampling periods. It produced tremendous numbers of Culex pipiens in great part due to foreign objects floating in the water which provided ideal sites for mosquito oviposition.

Most lagoons became anaerobic at some time during the night. It was necessary, therefore, to sample throughout the night to obtain data on the length of time the dissolved oxygen was below 2 ppm. As was to be expected, a great range of variation was found, the chronically anaerobic lagoons dropping below that level almost at sundown and the normally aerobic ones suffering no more than an hour or two just before dawn. Even in winter, with an ice covering on the water, the better lagoons remained aerobic all day and about half of the hours of darkness. However, when the ice was covered with snow, anaerobicity set in after the first full day. This is the major cause of winter fish mortality even in the best lagoons.

Occasionally in this region even the best lagoons cause complaints due to odors. This usually occurs in summer (August) on those occasions when drought conditions prevail and the amount of water flowing through the lagoons is reduced. Under such conditions, the advent of windy conditions causes considerable roiling of the water which increases turbidity to the point where photosynthesis is impossible at which time anaerobic bacteria gain dominance and objectionable odors are produced. This also will eliminate fish, of course.

Aside from marginal and emergent vegetation (as well as gross floating objects such as beer cans, tires, etc.) affording oviposition sites for mosquitoes, it has frequently been observed that certain lagoons produce hordes of mosquitoes while others do not. We had theorized that there was probably some olfactory attractant produced in troublesome lagoons which made them attractive to mosquitoes seeking oviposition sites. With this in mind, an Eckman dredge sample was taken on April 12, 1965 at 2 PM from a lagoon which had a great number of egg rafts of Culex mosquitoes. The dredge sample was taken from the bottom at a depth of 2.5 ft. and a water

sample was taken from immediately above this point at a depth of 1.5 ft. These samples were submitted to the Experiment Station Chemical Analytical Laboratories where they were analysed by gas chromatography techniques for volatile organic acids. The results revealed that in the water there were acetic and propionic acids plus the palmitate and pentadecanoate methyl esters; in the sludge there were acetic, propionic, isobutyric, butyric and isovaleric acids plus caprylate, caprate, laurate, tridecanoate, pentadecoanate, palmitate, and stearate methyl esters.

Based on these leads, laboratory colonies were exposed to various concentrations of most of the organic acids listed but the desired response, namely oviposition, was erratically or not at all produced. However, utilizing a technique wherein carbon dioxide was introduced into the test medium by a CO_2 distributor, a considerable response was obtained thus confirming reports by others that CO_2 plays a definite role in attracting mosquitoes and stimulating oviposition. Chemo-attraction is a very complex phenomenon and remains a relatively unexplored area for future investigation. In the present study it was not pursued further primarily because of the expense involved in getting analyses made.

Further studies on oviposition were carried out using artificial "oviposition blocks" consisting of 18 x 18 x 3 inch polystyrene plastic blocks which were subdivided into four cells each measuring 6 x 6 x 3 inches, the total area sampled per block encompassing one square foot. These were anchored in various lagoons and yielded considerable information on how attractive the individual types of lagoons were to mosquitoes. Unfortunately, an insufficient number of blocks was used to yield statistically meaningful data with regard to area sampled compared to total surface area of the lagoons. However, these demonstrated again that, with or without vegetation, a lagoon may attract mosquitoes for oviposition almost directly proportional to how anaerobic it is and for how long this condition prevails. Further, we are not convinced that CO_2 content in these lagoons is necessarily the only cause-and-effect factor to be considered.

It had been postulated that the enormous rafts of eggs of midges, or exuviae of midges which had emerged, might serve as oviposition sites for mosquitoes. In this study it was found that the presence of midge eggs or exuviae floating on the surface had no effect on mosquito oviposition. Both the egg shells and exuviae sank too quickly and thus even temporary oviposition sites were quite ephemeral.

Another aspect of water quality in midwestern oxidation lagoons concerned stratification, i.e., aerobic water conditions overlying anaerobic conditions in the same lagoon. On July 12, 1965, analyses showed a municipal lagoon to have no dissolved oxygen at depths of 2.5 ft. and below whereas samples collected at 6-inch depths varied from 5.9 to 33.4 ppm of dissolved oxygen in four sampling periods during one day (the first at dawn, the last at midafternoon). This stratification phenomenon held until Sept. 10, 1965, at which time a "turn-over" became evident and

dissolved oxygen was again present throughout the lagoon. During all this time, algal mats densely inhabited by midge larvae were present only from shore to the 2.5 ft. water depth area, about 7 feet from shore.

Further studies on the distribution of midge larvae on lagoon bottoms showed that it consisted of a concentric ring around the periphery of the lagoon from the shore line to about 8 feet from shore or wherever the water depth was about 30 inches. Depending on the slope of the lagoon bank, therefore, if insecticidal treatment seems justified, only an 8-10 foot area around the lagoon need be treated. One lagoon was so treated in this study using 10% Diazinon granules on walnut-shell carrier. Excellent mortality of midge larvae resulted. Treatment of another lagoon was observed where 5% malathion granules (actually, a special pelletized formulation) was used, again with very high mortality of midge larvae. Such treatments must be used with discretion to avoid fouling effluent waters with insecticides that might have a harmful effect in waters below the lagoon.

CONCLUSIONS

We are eminently satisfied with the results of this investigation as far as it was pursued. As usual, it raised numerous questions which leave a rich area for future investigation.

In the final analysis, construction and management are the major factors in operating these facilities. Engineers should be encouraged to design lagoons with banks as steep as consistent with the nature of the soil so that the water depth drops as rapidly as possible to 30 inches. This will narrow the band of midge production. Emergent and marginal vegetation must be controlled to prevent mosquito production. Most importantly, provision must be made rapidly to lead effluent water away from the lagoons to prevent marshy areas where mosquitoes breed.

The phenomenon of midge production is closely correlated with age and load of the lagoons. The evolution of a lagoon from a new, lightly loaded one to an older, more heavily loaded one need not be troublesome from the standpoint of insect production. Naturally occurring predators invade new lagoons almost as rapidly as do the pest species. A lagoon should never be treated with oil and with insecticides only under extreme conditions. However, it is entirely feasible to treat a lagoon with insecticides for midge control but great discretion should be used. There is still great need for development of an aquatic herbicide which will control emergent and marginal plant growth without harming the algae in the lagoons.

Mosquitoes of great public health importance do breed in and around lagoons. Culex pipiens complex and Culex tarsalis, both vectors of encephalitis, pose a real threat in the Midwest. It appears that Anopheles punctipennis is adapting to these artificial impoundments and may become of considerable public health importance.

In the present state of our knowledge, it seems unprofitable to introduce predatory species of insects into lagoons. If conditions are favorable they will appear naturally. Much additional work should be done to find small fish which can survive the erratic winter weather in the Midwest. However, annual stocking with Gambusia is entirely feasible but the effectiveness of this maneuver is not known. Further work should be done on pathogenic control of midges in lagoons.

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TABLE I

SIZE IN ACRES, LOAD IN POUNDS OF B.O.D. PER ACRE PER DAY: AGE IN YEARS AND THE AVERAGE PER SQUARE FOOT OF THE THREE DOMINANT SPECIES OF MIDGES FOR EACH LAGOON

Lagoon	Size	Load	Age	G. barbipes	C. plumosus	T. punctipennis
A	4.40	2.6	1.5	16362	0	0
B	0.45	19.0	2.0	10701	0	6
C	1.40	23.0	1.5	8800	66	0
D	12.50	20.0	1.0	6238	192	54
E	2.00	25.1	1.0	6072	0	0
F	4.50	20.0	1.5	3488	0	2
G	11.00	--	--	3733	0	0
H	0.50	32.0	4.0	1159	272	52
I	1.00	34.0	4.0	1113	284	184
J	35.40	30.0	1.0	1090	173	9
K	1.50	18.0	0.5	873	505	1649
L	1.25	30.0	0.5	469	0	142
M	3.50	--	--	392	568	8
N	0.88	50.0	5.0	221	434	477
O	15.00	37.0	7.0	37	793	1619
P	5.00	--	--	292	1272	32
Q	4.70	35.0	6.0	322	2262	374
R	0.25	78.0	6.0	8	71	1

TABLE II

GROUPING DATA INTO THREE TYPES OF LAGOONS ON THE BASIS OF LOAD IN POUNDS OF B.O.D. PER ACRE PER DAY, AGE IN YEARS AND DENSITY PER SQUARE FOOT OF THE THREE DOMINANT SPECIES OF MIDGES

Type	Load	Age	G. barbipes	C. plumosus	T. punctipennis
I	18.3	1.4	7913	37	9
II	32.0	3.0	1121	243	82
III	50.0	6.0	212	966	501

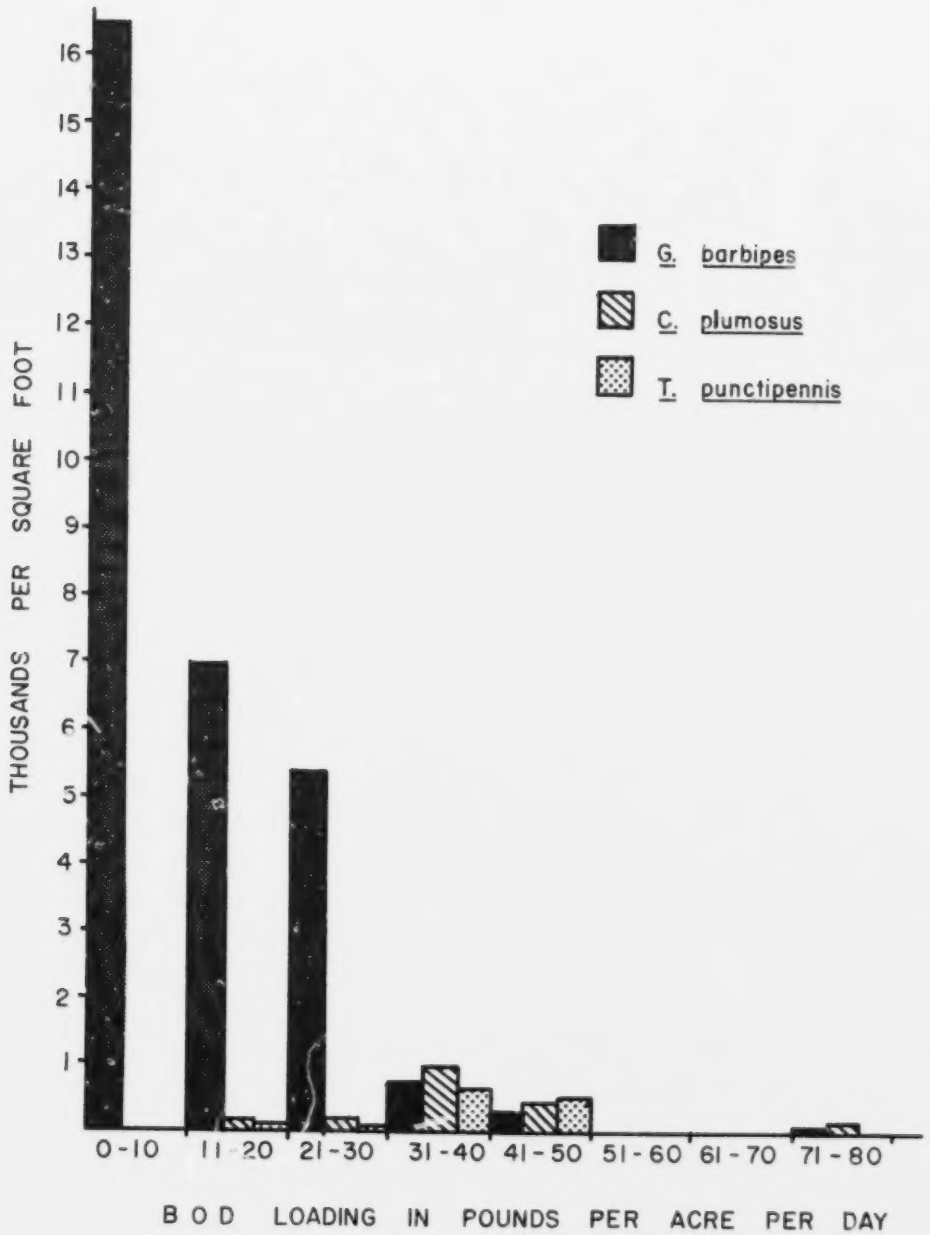

FIGURE 1. AVERAGE DENSITY PER SQUARE FOOT OF MIDGES IN LAGOONS WITH DIFFERENT B. O. D. LOADING

TABLE III

SPECIES OF AQUATIC INSECTS ASSOCIATED

WITH WASTE STABILIZATION LAGOONS

OF THREE TYPES

Species	Type I	Type II	Type III
Diptera			
Chironomidae			
Glyptotendipes (Phytotendipes) barbipes (Staeger)	7913.0[a]	1121.0	212.0
Chironomus (Chironomus) plumosus (Linnaeus)	37.0[c]	243.0[b]	966.0
Chironomus (Chironomus) attenuatus Walker	x	--	--
Chironomus (Chironomus) fulvipilus Rempel	x	--	--
Chironomus (Chironomus) riparius Meigen	x	--	--
Tanypus punctipennis Meigen	9.0	82.0	501.0
Anatopynia (Psectrotanypus) dyari (Coq.)	x	x	--
Micropsectra nigripila (Johannsen)	x	--	--
Clinotanypus sp.	x	--	--
Ceratopogonidae			
Palpomyia sp.	14.0	7.0	0.2
Culicoides sp.	0.2	--	--
Chaoboridae			
Chaoborus punctipennis (Say)	1.0	2.0	--
Culicidae			
Culex pipiens pipiens Linnaeus	x	x	xx[d]
Culex tarsalis	--	x	xx
Psychodidae			
Psychoda prob. alternata Say	.2	x	5.4
Telmatoscopus albipunctatus (Will.)	--	0.5	1.0
Ephydridae			
Ephydra sp.	1.3	.6	2.5
Brachydeutera argentata (Walk.)	0.4	1.3	2.7
Phoridae			
Megaselia sp.	--	--	1.0

TABLE III (Continued)

Species	Type I	Type II	Type III
Tabanidae			
Tabanus stygius Say	x	x	--
Chrysops sp.	x	x	x
Stratiomyidae			
Stratiomyia sp.	x	x	xx
Odontomyia sp.	x	x	xx
Syrphidae			
Eristalis sp.	x	x	xx
Muscoid Puparia	x	x	xx
Coleoptera			
Dytiscidae			
Laccophilus sp.*	.4	1.3	1.2
Bidessus lacustris Say	x	--	x
Thermonectes ornaticollis Aube	--	--	x
Acilius sp.	--	x	--
Hygrotus nubilis (LeC.)	x	x	x
Hydrophilidae			
Berosus infuscatus LeC.	2.0	2.6	--
Tropisternus lateralis nimbatus Say	.8	1.3	1.0
Tropisternus mexicanus mexicanus LaP.	.5	x	x
Tropisternus mexicanus striolatus LeC.	x	x	x
Helochares maculicollis Mulsant	--	x	x
Helophorus sp.	x	--	--
Hydrophilus triangularis Say	x	--	--
Enochrus nebulosus Say	x	x	x
Gyrinidae			
Dineutus assimilis Kirby	x	x	x
Dineutus ciliatus Forsberg	--	x	--
Haliplidae			
Peltodytes litoralis Matheson	x	x	x
Haliplus triopsis Say	--	x	--
Odonata			
Libellulidae			
Plathemis lydia Drury	4.0	2.1	1.2
Perithemis tenera Say	0.1	0.4	--
Pachydiplax longipennis Burmeister	--	x	--

* Includes Laccophilus maculosus Say, L. fasciatus Aube, and L. proximus Say

TABLE III (Continued)

Species	Type I	Type II	Type III
Aeschnidae			
Anax junius Drury	x	x	x
Coenagrionidae			
Ischnura verticalis (Say)	0.2	x	24.0[e]
Enallagma hageni (Walsh)	1.0	--	.5
Ephemeroptera			
Baetidae			
Caenis sp.	0.5	2.0	--
Cloeon sp.	--	0.2[e]	--
Hemiptera			
Belostomatidae			
Belostoma sp.	x	x	x
Nepidae			
Ranatra fusca P.B.	x	x	--
Notonectidae			
Notonecta undulata Say			
Mesovelidae			
Mesovelia mulsanti White	x	x	--
Corixidae			
Corisella inscripta (Uhler)	x	x	x
Sigara (Arctosigara) decoratella (Hung.)	x	x	x
Gerridae			
Gerris marginatus Say	x	x	--
Saldidae			
Saldula sp.	--	--	x[e]
Lepidoptera			
Pyralidae			
Synclita sp.	--	--	2.4[e]

a Number per square foot from quantitative sample
b Not present
c Occasionally occurring in qualitative sample
d Abundant in qualitative sample
e Restricted to one lagoon

TABLE IV

SUMMARY OF DATA FOR EIGHT OXIDATION LAGOONS; INCLUDING AGE IN YEARS, B.O.D.[a] IN POUNDS PER ACRE PER DAY, SIZE IN ACRES, AVERAGE DEPTH IN INCHES AND INCLINE OF BANK IN INCHES PER FOOT

Lagoon[b]	Location and Type	Age	Load	Size	Av. Depth	Bank Incline
1 - AW	Humane Society - Primary	4.0	Unk[c]	0.1	21	1.8
2 - AW	Swine Farm - Primary	7.0	Unk	0.5	27	5.0
3 - AW	Swine Farm - Secondary	4.0	Unk	0.5	40	5.0
4 - M	Bear Creek - Primary	8.0	35.0	4.7	42	3.0
5 - R	South Drive - Primary	6.0	32.0	0.5	42	4.5
6 - SL	Woodhaven - Primary	3.0	17.0	1.0	32	4.8
7 - S	Moberly - Primary	6.0	Unk	2.0	38	3.5
8 - TC	Pine Grove - Primary	3.5	20.6	1.4	20	2.5

a Biochemical Oxygen Demand.

b AW (Animal Wastes), M (Municipal), R (Residential), SL (School Lagoon), S (Slaughterhouse Wastes), and TC (Trailer Court).

c Unknown.

TABLE V

NUMBER OF EGG RAFTS AND LARVAE RECOVERED FROM SELECTED OXIDATION LAGOONS IN MISSOURI FROM APRIL-AUGUST, 1965-66

Lagoon[a]	Number of Egg Rafts and Larvae/Month											
	April		May		June		July		August		Total	
	Rafts	Larvae	Rafts	Larvae	Rafts	Larvae	Rafts	Larvae	Rafts	Larvae	Rafts	Larvae
1 - AW*	17	23	5	41	11	61	NS	NS	NS	NS	33	125
2 - AW	35	NS	43	NS	3,580	176	1,444	19,223	1,033	42,356	6,135	61,755
3 - AW	0	NS	0	NS	128	9	213	1,419	697	33,267	1,038	34,695
4 - M	NS	NS	15	NS	173	149	15	52	40	82	243	283
5 - R	4	NS	6	NS	41	142	14	190	21	175	86	507
6 - SL*	3	0	5	0	11	21	0	0	0	0	19	21
7 - S*	NS	NS	15	47	25	81	11	53	NS	NS	51	181
8 - TC	8	NS	23	NS	51	37	53	175	79	421	216	633

a See Table IV for explanation of AW, M, R, SL, S and TC.

* - 1965 data; all other 1966.

NS - Not sampled.

TABLE VI

LIST OF MOSQUITO SPECIES COLLECTED FROM THE ENVIRONS OF A TYPICAL MUNICIPAL LAGOON, COLUMBIA, MISSOURI, DURING 1965-66

Species	Bite Counts	Stream Sampling	CDC Light Trap
Aedes canadensis	+	-	-
Aedes triseriatus	+	-	+
Aedes trivittatus	+	-	-
Aedes vexans	+	-	+
Anopheles punctipennis	+	+	+
Anopheles quadrimaculatus	+	-	+
Culex erraticus	+	-	+
Culex pipiens complex	+	+	+
Culex salinarius	+	+	+
Culex tarsalis	-	+	+
Culiseta inornata	+	+	+
Psorophora ferox	+	-	-

TABLE VII

CHECKLIST OF MOSQUITOES IN MISSOURI

Aedes Meigen 1818
- *aegypti* (Linnaeus)
- *atlanticus* Dyar & Knab
- *atropalpus* (Coquillet)
- *canadensis* (Theobald)
- *cinereus* (Meigen)
- *dorsalis* (Meigen)
- *dupreei* (Coquillet)
- *flavescens* (Mueller)
- *grossbecki* Dyar & Knab
- *hendersoni* Cockerell
- *infirmatus* Dyar & Knab
- *nigromaculis* (Ludlow)
- *riparius* Dyar & Knab
- *sollicitans* (Walker)
- *sticticus* (Meigen)
- *stimulans* (Walker)
- *thibaulti* Dyar & Knab
- *tormentor* Dyar & Knab
- *triseriatus* (Say)
- *trivittatus* (Coquillet)
- *vexans* (Meigen)

Anopheles Meigen 1818
- *barberi* Coquillet
- *crucians* Wiedmann
- *pseudopunctipennis* Theobald
- *punctipennis* (Say)
- *quadrimaculatus* Say
- *walkeri* Theobald

Culex Linnaeus 1758
- *erraticus* (Dyar & Knab)
- *peccator* (Dyar & Knab)

Culex Linnaeus 1758 (Continued)
- *pipiens* Linnaeus
- *quinquefasciatus* Say
- *restuans* Theobald
- *salinarius* Coquillet
- *tarsalis* Coquillet
- *territans* Walker

Culiseta Felt 1904
- *impatiens* (Walker)
- *inornata* (Williston)
- *melanura* (Coquillet)

Mansonia Blanchard 1901
- *perturbans* (Walker)

Orthopodomyia Theobald 1904
- *alba* Baker
- *signifera* (Coquillet)

Psorophora Robineau-Desvoidy 1827
- *ciliata* (Fabricius)
- *confinnis* (Arribalzaga)
- *cyanescens* (Coquillet)
- *discolor* (Coquillet)
- *ferox* (Humboldt)
- *horrida* (Dyar & Knab)
- *howardi* (Coquillet)
- *longipalpis* Roth
- *signipennis* (Coquillet)
- *varipes* (Coquillet)

Toxorhynchites Theobald 1901
- *septentrionalis* Dyar & Knab

Uranotaenia Arribalzaga 1891
- *sapphirina* (Osten-Sacken)